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Optimization of Cutting Parameters on Surface Roughness Using CNC Turning

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***Abstract*—Paper Optimization of cutting parameters is important for achievement of high quality. Taguchi method of experimental design is one of the widely accepted techniques for off line quality assurance of products and processes. In this investigation, comparison of TiBN coated on carbide tool using Physical Vapor Deposition (PVD) machine and uncoated carbide tool, under dry condition. The chemical composition of TiBN is 0.55% Ti, 0.22%B, 0.22%N .The Work piece material is taken as Aluminium and Copper. Experiment is carried out using Taguchi's L27 orthogonal array. The effect of cutting parameters on SR was evaluated and optimum cutting conditions for minimizing the SR was determined. Analysis of variance (ANOVA) was used for identifying the significant parameters affecting the responses and Comparing the result with genetic algorithms.**

***Index Terms*—Computer numerical control, Surface Roughness, Optimization, Tool**

I. INTRODUCTION

Manufacturing enterprises presently have to deal with growing demands for improved product quality, greater product unpredictability, shorter product life-cycles, cheap cost, and global struggle [1] In the field of machining, manufacturers are turning increasingly more often to automation as an effective way to meet these demands. A solution issue for an unattended and automated machining system is the development of reliable and robust monitoring systems. Turning is the removal of metal from the outer diameter of a rotating cylindrical work piece. Turning is used to reduce the diameter of the work piece, usually to a specified dimension, and to produce a smooth finish on the metal. Often the work piece will be turned so that adjacent sections have different diameters. With all the viewpoints above, this paper considers three cutting parameters are cutting depth, feed rate, speed with coated and uncoated tool; the response is to optimize surface roughness in CNC finish turning. In this case, dry machining of aluminum alloy, the machining condition which affects the quality of the generated surface [2-5]. According to previous works [6-11] the various types of surface roughness depend on the nature of the tool, the work piece material, the cutting conditions and the machining operation. Physical and chemical vapour deposited coatings offer today a powerful alternative to improve further the cutting performance of the cutting materials.

The flexibility of coating processes especially of the physical vapor deposition (PVD) method, well supported by the superior and controllable properties of modern coatings are responsible for the almost exclusive world wide application of coated tools [12-15]. The few of the experimental works was performed finish turning, PVD coated carbide insert at high cutting speed. Finally, the last section discusses the GA techniques applied in optimization of machining parameter systems and their advantages and drawbacks as regards facilitating their selection according to the optimization purpose.

II. TAGUCHI METHOD DESIGN OF EXPERIMENTS:

The general steps involved in the Taguchi Method are as follows:

1. Define the process objective, or more specifically, a target value for a performance measure of the process. This may be a flow rate, temperature, etc. The target of a process may also be a minimum or maximum; for example, the goal may be to maximize the output flow rate. The deviation in the performance characteristic from the target value is used to define the loss function for the process.
2. Determine the design parameters affecting the process. Parameters are variables within the process that affect the performance measure such as temperatures, pressures, etc. that can be easily controlled. The number of levels that the parameters should be varied at must be specified. For example, a temperature might be varied to a low and high value of 40 C and 80 C. increasing the number of levels to vary a parameter at increases the number of experiments to be conducted.
3. Create orthogonal arrays for the parameter design indicating the number of and conditions for each experiment. The selection of orthogonal arrays is based on the number of parameters and the levels of variation for each parameter, and will be expounded below.
4. Conduct the experiments indicated in the completed array to collect data on the effect on the performance measure
5. Complete data

III. METHODOLOGY

A. For Experimental Work

i) The material and tool inserts are selected based on the problem identification study.
ii) Identifying different ranges of input parameters and their levels
iii) Measuring surface roughness (Ra) using surface roughness tester.

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B. For Theoretical Work

i) Calculation of surface roughness

ii) Formation of regression equation using minitab software Units

C. For Analysis Work

Developing algorithm for optimization using Minitab.

ii) Developing analysis for ANOVA table

ii) Developing algorithm for optimization using c++ coding

ii) Comparing the optimization results.

iii) Validation of results.

II. DESCRIPTION OF EXPERIMENT

The main objective of the work is to establish a relation between cutting speed, feed and depth of cut on SR. CU & AL material was taken as the work piece materials for all trials diameter of 12 mm and machined length of 4 mm. The chemical composition of the work piece is given in table A. The experiments were conducted in Fanuc CNC lathe. The range of cutting parameters were selected based on past experience, data book and available resources. In this investigation, TiBN coated and uncoated TNMG 160404 coated with TiBN of 6 µm was used as the insert. SR was measured for both cases by the mitutoyo surface roughness tester. In the present work, three parameters each set at three levels were chosen for experimentation. The turning parameters and their levels chosen are presented in Table B. In order to have a complete study of turning process, the range of parameters selected, and an appropriate planning of experimentation is essential to reduce the cost and time consuming. Hence, an experimental plan based on Taguchi's L_{27} Orthogonal array has been selected. The factors were assigned to the columns 1–3, respectively, and 27 experiments were carried out under dry condition with different combinations of parameters levels.

TABLE A

CHEMICAL COMPOSITION OF COPPER AND ALUMINIUM.

composition	Cu	Sn	Pb	Zn	-
%weight	93	1.5	1.5	4	-
composition	Al	Si	Fe	Mn	others
%weight	99.5	0.25	0.40	0.05	0.1

Parameter	Designation	Level 1	Level 2	Level 3
Cutting speed (m/min)	v	60	70	80
Feed (µm/rev)	f	10	40	80
Depth of cut (µm)	d	50	100	150

TABLE B

Machining Parameters and Levels

There are three categories of quality characteristic in the analysis of the S/N ratio (1) the-lower-the-better, (2) the-higher-the-better and (3) the-nominal-the-better. Since the quality characteristic is to be minimized, the-lower-the-better category is used to calculate the S/N ratio for SR. Equation (1) shows the smaller the better characteristic.

$\eta = -10\log_{10}\ 1/n\Sigma_i^n\, y^2$

Where:

η = Signal to noise ratio

n = Number of repetitions of experiment

y = Measured value of quality characteristic

V, EXPERIMENTAL RESULTS AND DISCUSSIONS

A. Design and optimal of Taguchi:

Uncoated Tool:

Aluminium:

As per Taguchi's method the total DOF of the selected OA must be greater than or equal to the total DOF required for the experiment. So, an L27 - OA (a standard three-level orthogonal array) having 26 DOF was selected for the present work. The non-linear relationship among the process parameters, if it exists, can only be revealed if more than two levels of the parameters are considered. Thus each selected parameter was analyzed at three levels.

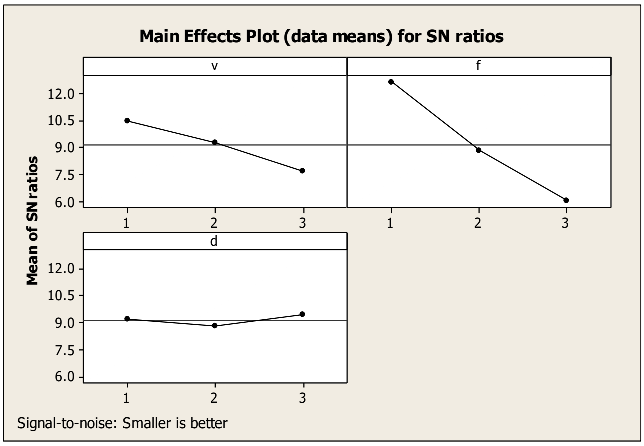

Fig 1. Main effects plot for aluminium

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TABLE 1

RESPONSE OF ALUMINIUM AND COPPER: **UNCOATED** **COATED**

Exp. No	V(m/min)	F(µm/rev)	D(µm)	SR(al)	SR(Cu)	SR(al)	SR(Cu)
1	60	10	50	0.27	0.54	0.3	1.23
2	60	10	50	0.19	1.42	0.33	0.79
3	60	10	50	0.11	1.55	0.45	0.55
4	60	40	100	0.35	1.74	0.33	1.07
5	60	40	100	0.36	1.42	0.27	0.91
6	60	40	100	0.26	1.44	0.3	1.69
7	60	80	150	0.57	3.09	0.39	1.92
8	60	80	150	0.27	1.69	0.31	1.51
9	60	80	150	0.32	2.71	0.36	2.65
10	70	10	100	0.28	0.33	0.45	0.46
11	70	10	100	0.23	0.28	0.22	1.03
12	70	10	100	0.19	0.34	0.33	0.2
13	70	40	150	0.36	1.45	0.42	1.28
14	70	40	150	0.29	1.24	0.43	1.34
15	70	40	150	0.39	0.77	0.35	0.69
16	70	80	50	0.68	2.82	0.72	2.57
17	70	80	50	0.39	2.22	0.67	2.52
18	70	80	50	0.33	1.3	0.44	2.76
19	80	10	150	0.25	1.35	0.65	0.53
20	80	10	150	0.24	0.67	0.38	0.77
21	80	10	150	0.31	0.87	0.35	0.51
22	80	40	50	0.63	3.7	0.68	0.61
23	80	40	50	0.27	0.68	0.94	0.92
24	80	40	50	0.25	1.34	0.5	1.1
25	80	80	100	0.65	1.87	0.56	1.94
26	80	80	100	0.6	2.76	0.66	2.49
27	80	80	100	0.6	2.17	0.74	1.97

TABLE 1I
TAGUCHI ANALYSIS OF ALUMINIUM:
SR versus v, f, d

level	V	f	d
1	9.984	11.886	8.476
2	10.361	10.138	9.611
3	8.309	6.631	10.568
Rank	3	1	2

TABLE III
ANOVA FOR SR OF ALUMINIUM

Source	DF	SS	MS	F	P
V	2	0.05	0.02	1.55	0.237
F	2	0.21	0.10	6,38	0.007
D	2	0.02	0.01	0.75	0.485
Error	20	0.34	0.01		
Total	26	0.63			

S = 0.130815 R-Sq = 46.46% R-Sq(adj) = 30.40%

The experimental responses were reported in the table 1. The averages of surface roughness were calculated as 0.357 µm.

From table 2. found that the rank value for machining parameters and it is stated that feed has the strongest influence on SR followed by depth of cut. The result of the ANOVA for SR was shown in Table 3. It is observed that feed (p-value = 0.007) is the most significant parameter. The main effects plots are used to determine the optimal design conditions to obtain the optimum SR. It represents in fig 1.

Optimal value = v1f1d3

Copper:

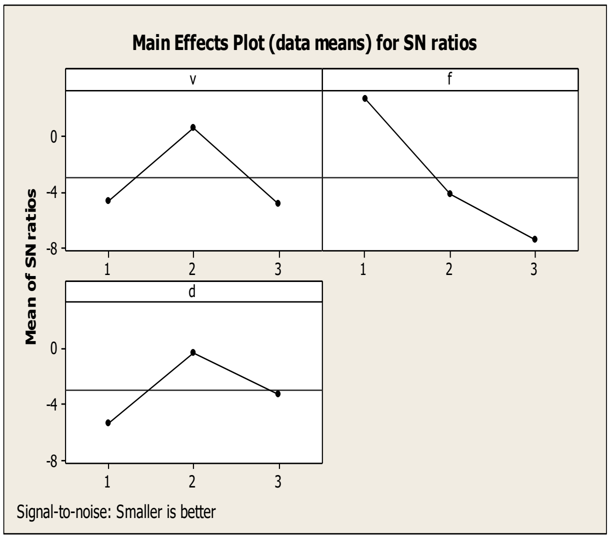

Fig 2. Main effects plot for copper

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TABLE IV.
TAGUCHI ANALYSIS OF COPPER:
SR versus v, f, d

level	V	f	d
1	-3.703	1.679	-4.826
2	-1.359	-4.077	-1.146
3	-3.689	-6.353	-2.779
Rank	3	1	2

TABLE V.
ANOVA FOR SR OF COPPER

Source	DF	SS	MS	F	P
V	2	0.03	0.18	0.43	0.656
F	2	6.49	3.24	7.48	0.004
D	2	0.64	0.32	0.75	0.487
Error	20	8.68	0.43		
Total	26	16.19			

S = 0.658930   R-Sq = 46.39%   R-Sq(adj) = 30.31%

The experimental response was reported in the table 1. The average of surface roughness was calculated as 1.55 µm. From table 4. found that the rank value for machining parameters and it is stated that feed has the strongest influence on SR followed by depth of cut. The result of the ANOVA for SR was shown in Table 5. It is observed that feed (p-value = 0.004) is the most significant parameter. The main effects plots are used to determine the optimal design conditions to obtain the optimum SR. It represents in fig 2.

Optimal value = v3f1d3

Coated Tool:

Aluminium:

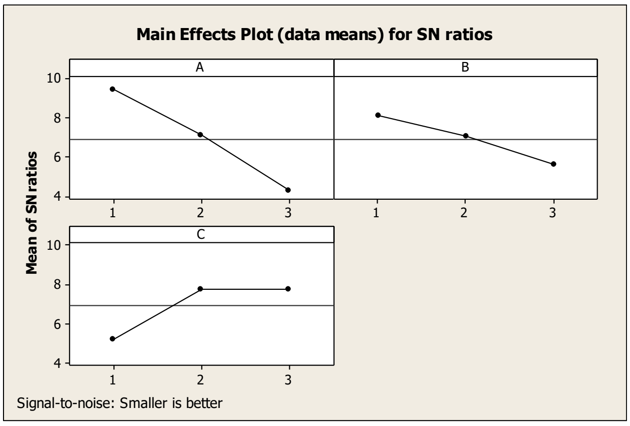

Fig 3. Main effects plot for aluminium

TABLE VI
TAGUCHI ANALYSIS OF ALUMINIUM:
SR versus v, f, d

level	V	F	D
1	9.388	8.111	5.200
2	7.086	7.031	7.761
3	4.257	5.588	7.770
Rank	1	3	2

TABLE VII
ANOVA FOR SR OF ALUMINIUM

Source	DF	SS	MS	F	P
V	2	0.03	0.16	12.55	0.000
F	2	0.10	0.05	4.11	0.032
D	2	0.12	0.06	4.73	0.021
Error	20	0.26	0.01		
Total	26	0.82			

S = 0.114501   R-Sq = 68.13%   R-Sq(adj) = 58.57%

The experimental response was reported in the table 1. The averages of surface roughness were calculated as 1.55 µm. From table 6. found that the rank value for machining parameters and it is stated that cutting speed has the strongest influence on SR followed by depth of cut. The result of the ANOVA for SR was shown in Table 7. It is observed that cutting speed (p-value = 0.000) is the most significant parameter. The main effects plots are used to determine the optimal design conditions to obtain the optimum SR. It represents in fig 3.

Optimal value = v1f1d3

Copper:

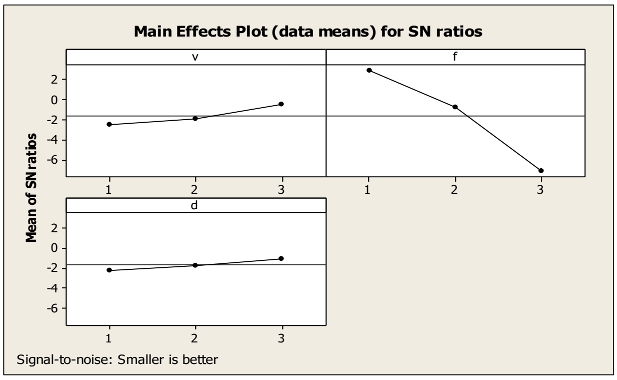

Fig 4. Main effects plot for copper

TABLE VIII
TAGUCHI ANALYSIS OF COPPER
SR versus v, f, d

level	V	f	d
1	-2.511	2.904	-2.181
2	-1.974	-0.766	-1.706
3	-0.499	-7.122	-1.096
Rank	2	1	3

The experimental responses were reported in the table 1. The averages of surface roughness were calculated as 1.33 µm. From table 8. found that the rank value for machining parameters and it is stated that feed has the strongest influence on SR followed by cutting speed. The result of the ANOVA for SR was shown in Table 9. It is observed that feed (p-value = 0.000) is the most significant parameter. The main effects plots are used to determine the optimal design conditions to obtain the optimum SR. It represents in fig 4.

Optimal value = v3f1d3

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TABLE IX
ANOVA FOR SR OF COPPER

Source	DF	SS	MS	F	P
V	2	0.24	0.12	0.88	0.430
F	2	12.25	6.12	44.71	0.000
D	2	0.20	0.10	0.73	0.494
Error	20	2.74	0.13		
Total	26	15.43			

S = 0.370169 R-Sq = 82.24% R-Sq(adj) = 76.92%

B. Design and Optimal of GA

Best fitness for minimization of surface roughness is shown below using genetic algorithm tool.
Variable =3(binary form)
Chromosome length = 10
Population size = 100,
Cross over probability = 0.8,
Mutation probability = 0.1,
Single point crossover
Current generation = 28
Uncoated tool:
1. Optimization value for aluminium:
Result generation = 79
Cutting speed = 60.136 m/min,
Feed rate = 10.20 µm/rev,
Depth of cut = 142.277 µm
Best fitness for minimization of surface roughness is 4.036 µm
2. Optimization value for copper:
Result generation = 5
Cutting speed = 64.98 m/min,
Feed rate = 10.205 µm/rev,
Depth of cut = 149. 82 µm
Best fitness for minimization of surface roughness is 4.804 µm
Coated tool:
1. Optimization value for aluminium:
Result generation = 1
Cutting speed = 60.89 m/min,
Feed rate = 10.27 µm/rev,
Depth of cut = 147.94 µm
Best fitness for minimization of surface roughness is 0.596 µm
2. Optimization value for copper:
Result generation = 30
Cutting speed = 77.82 m/min,
Feed rate = 10.00 µm/rev,
Depth of cut = 149. 02 µm
Best fitness for minimization of surface roughness is -13.804 µm

VI. CONCLUSION

The current investigation is focused on optimization and analysis of Turning during change of cutting parameters. From the study of result in turning was using Taguchi's techniques, ANOVA and GA. The following can be concluded from the present study.

1. The uncoated tool found that the aluminium optimum combination of input parameters for minimization of surface roughness found to be Cutting speed = 60.136 m/min, Feed rate = 10.20 µm/rev,Depth of cut = 142.277 µm. Best fitness for minimization of surface roughness is 4.036 µm using GA.
2. The copper optimum combination of input parameters for minimization of surface roughness found to be Cutting speed = 64.98 m/min, Feed rate = 10.205 µm/rev, Depth of cut = 149. 82 µm Best fitness for minimization of surface roughness is 4.804 µm using GA.
3. The aluminium optimum combination of input parameters for minimization of surface roughness found to be Cutting speed 60 m/min, Feed rate = 10 µm/rev, Depth of cut = 150 µm using taguchi optimal.
4. The copper optimum combination of input parameters for minimization of surface roughness found to be Cutting speed = 70 m/min, Feed rate = 10 µm/rev, Depth of cut = 100 µm using taguchi optimal.
5. The coated tool found that the aluminium optimum combination of input parameters for minimization of surface roughness found to be Cutting speed = 60.89 m/min, Feed rate = 10.27 µm/rev, Depth of cut = 147.94 µm. Best fitness for minimization of surface roughness is 0.596 µm using GA.
6. The copper optimum combination of input parameters for minimization of surface roughness found to be Cutting speed = 77.82 m/min,Feed rate = 10.00 µm/rev, Depth of cut = 149. 02 µm. Best fitness for minimization of surface roughness is -13.804 µm using GA.
7. The aluminium optimum combination of input parameters for minimization of surface roughness found to be Cutting speed 60 m/min, Feed rate = 10 µm/rev, Depth of cut = 150 µm using taguchi optimal.
8. The copper optimum combination of input parameters for minimization of surface roughness found to be Cutting speed = 80 m/min, Feed rate = 10 µm/rev, Depth of cut = 150 µm using taguchi optimal
9. From the R-sq value from anova table found that comparison found that TiBN provided the best surface roughness value

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